National Aeronautics and Space Administration

SmallSats supporting Deep Space Human Exploration

August 06, 2018

Andres Martinez, Program Executive,
Advanced Exploration Systems, HEOMD, NASA HQ

Background about me…

1990

THE DOCUMENT COMPANY XEROX
1990

XEROX PARC
1997

outride
2001

2003

2006

NASA
2007

National Advisory Committee for Aeronautics

Joseph S. Ames

NACA

Langley

Ames

Lewis

Dryden

NASA

1915

1939

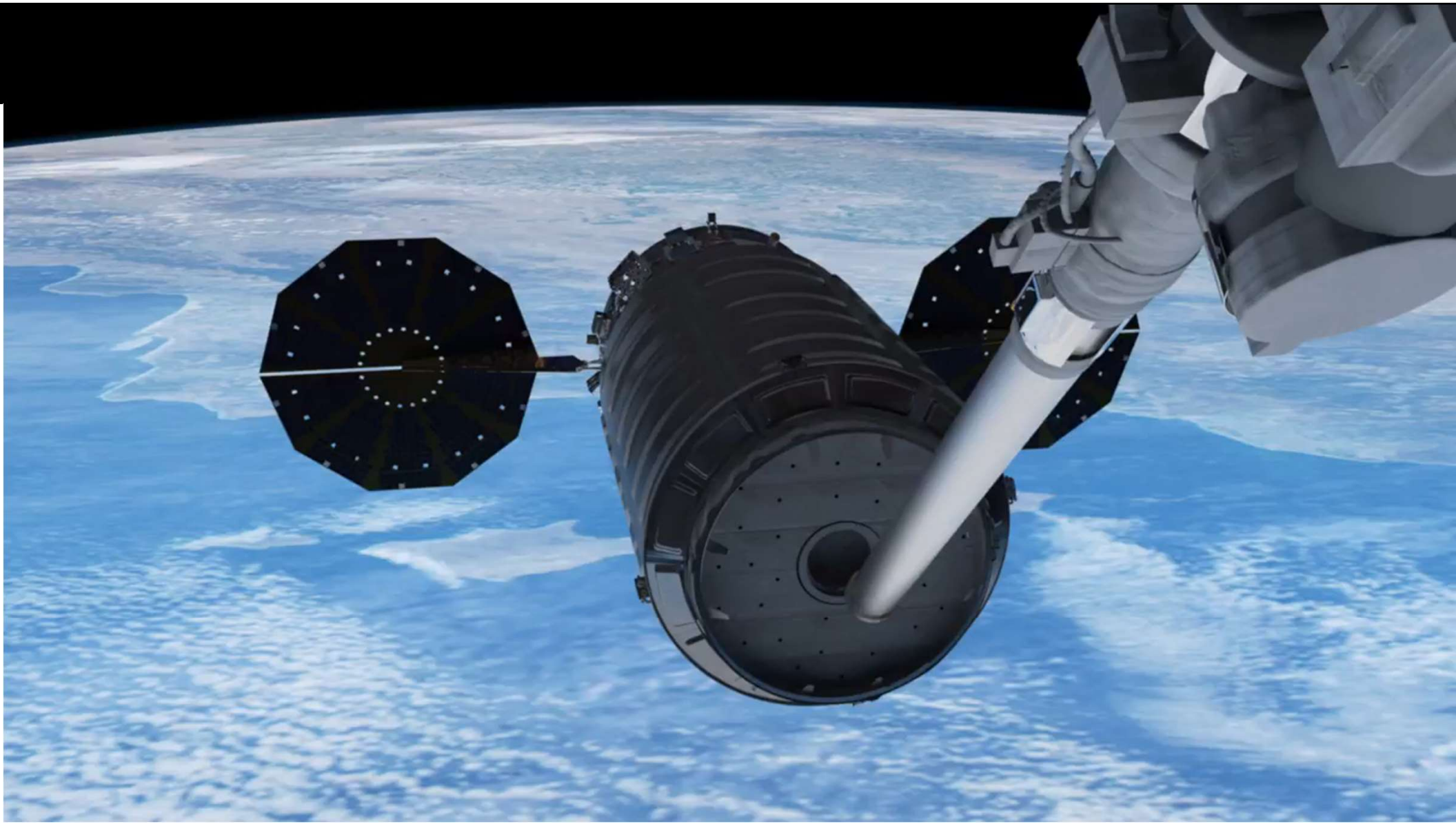
1940

1946

1958

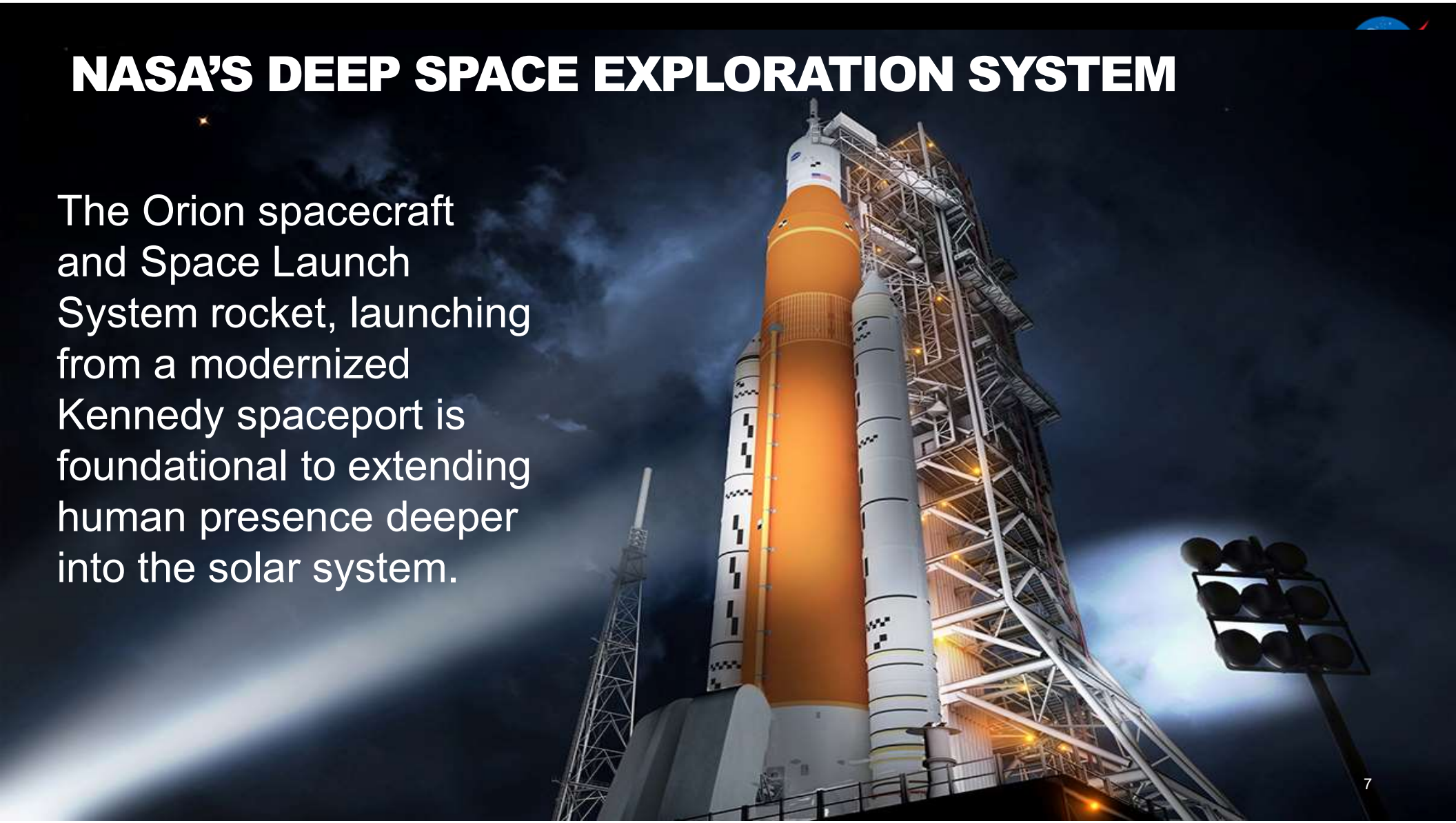
National Aeronautics and Space Administration

N



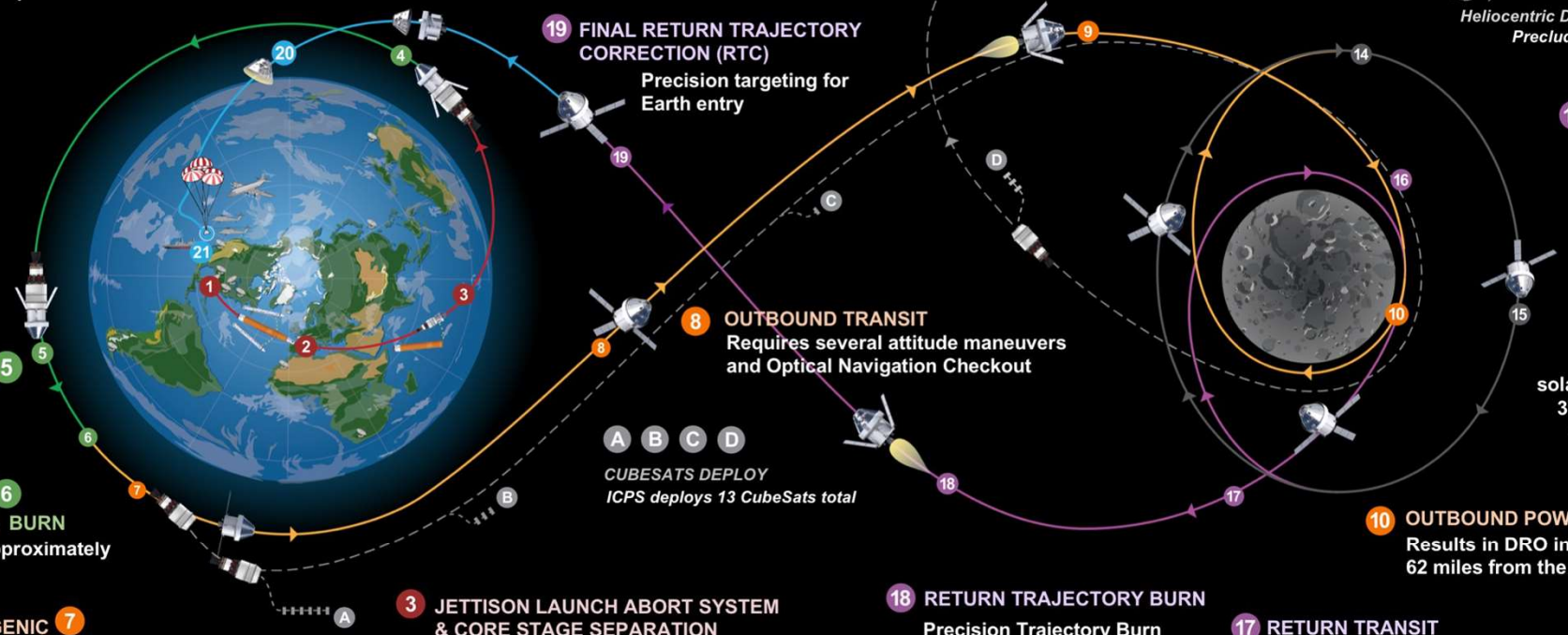
NASA'S DEEP SPACE EXPLORATION SYSTEM

The Orion spacecraft and Space Launch System rocket, launching from a modernized Kennedy spaceport is foundational to extending human presence deeper into the solar system.



EXPLORATION MISSION-1

The first uncrewed, integrated flight test of NASA's Orion spacecraft and Space Launch System rocket, launching from a modernized Kennedy spaceport



SPLASHDOWN 21
Pacific Ocean landing within view of the U.S. Navy recovery ships

20 RE-ENTRY INTERFACE
Enter Earth's atmosphere

4 ENTER EARTH ORBIT
Perform the perigee raise maneuver

9 OUTBOUND TRAJECTORY CORRECTION (OTC)
As necessary adjust trajectory for Lunar insertion to DRO

14 ORBIT INSERTION
Enter Distant Retrograde Orbit for next 6-10 days

Heliocentric Disposal
Precludes re-contact

LAUNCH 1
SLS and Orion lift off from pad 39B at Kennedy Space Center

19 FINAL RETURN TRAJECTORY CORRECTION (RTC)
Precision targeting for Earth entry

16 RETURN POWER FLY-BY (RPF)
RPF burn prep and return coast to Earth initiated

JETTISON ROCKET BOOSTERS 2
Solid rocket boosters separate

8 OUTBOUND TRANSIT
Requires several attitude maneuvers and Optical Navigation Checkout

15 DISTANT RETROGRADE ORBIT (DRO)
Burn maneuver and solar panel adjustment; 37,000 miles from the surface of the Moon

EARTH ORBIT 5
Systems check and solar panel adjustments

A B C D
CUBESATS DEPLOY
ICPS deploys 13 CubeSats total

TRANS LUNAR INJECTION (TLI) BURN 6
Burn lasts for approximately 20 minutes

10 OUTBOUND POWERED FLY-BY
Results in DRO insertion; 62 miles from the Moon

INTERIM CRYOGENIC PROPULSION STAGE (ICPS) SEPARATION 7
The ICPS provides enough thrust to circularize orbit and commit Orion to TLI

3 JETTISON LAUNCH ABORT SYSTEM & CORE STAGE SEPARATION
The LAS is no longer needed, Orion could safely abort at Anytime; core stage separation and engine shut down

18 RETURN TRAJECTORY BURN
Precision Trajectory Burn aiming for Earth's atmosphere

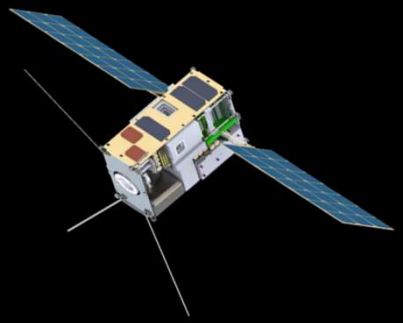
17 RETURN TRANSIT
Return Trajectory Correction burn prep; travel time 6-10 days

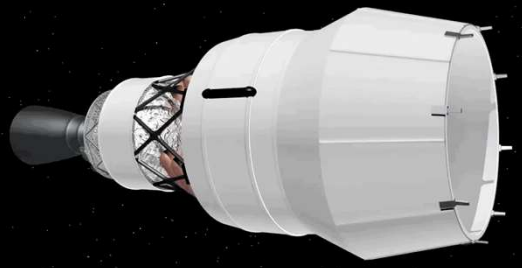
Launch | Earth Orbit | Trans Lunar | Lunar Orbit | Trans Earth | Earth Re-entry | Payload Orbit/Disposal

Total distance traveled: 1.3 million miles – Mission duration: 25.5 days – Re-entry speed: 24,500 mph (Mach 32) – 13 CubeSats deployed

EM-1 Secondary Payloads

INTERIM CRYOGENIC PROPULSION STAGE

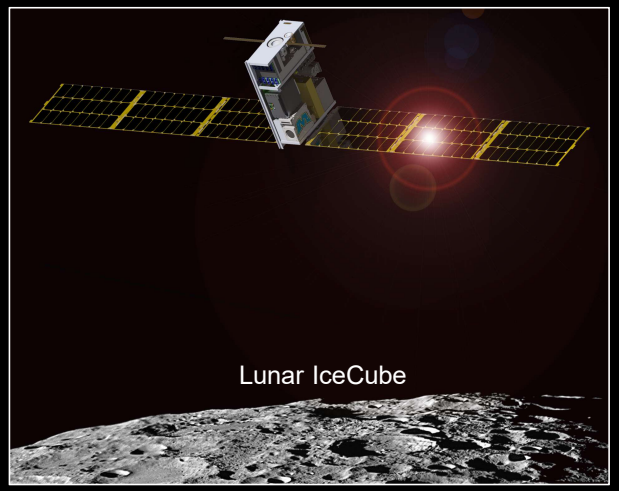


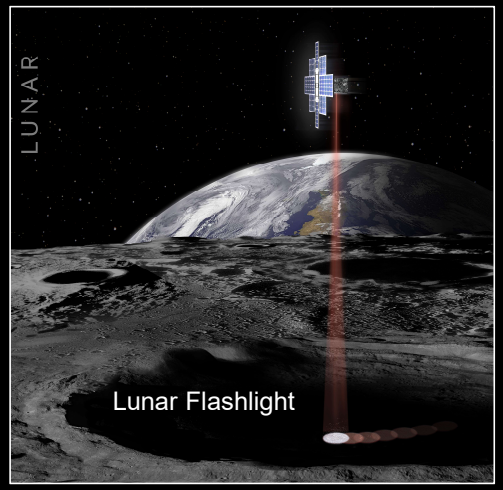


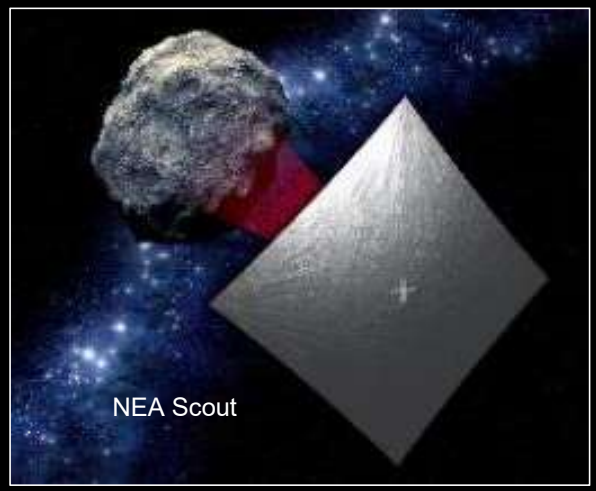
13 CUBESATS SELECTED TO FLY ON EM-1

- Lunar Flashlight
- Near Earth Asteroid Scout
- Bio Sentinel
- LunaH-MAP
- CuSP
- Lunar IceCube
- LunIR
- EQUULEUS (JAXA)
- OMOTENASHI (JAXA)
- ArgoMoon (ESA)
- STMD Centennial Challenge Winners: CU-E3, CisLunar Explorers, & Team Miles

HEOMD/AES Deep Space SmallSats: SLS EM-1 Secondary Payloads

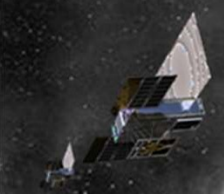






AES SmallSat Missions selected to contribute to key Human Exploration Strategic Knowledge Gaps and to Advance Key Technologies

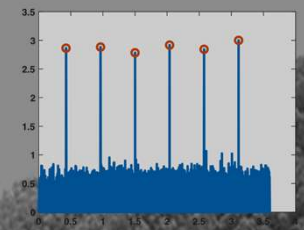
HEOMD/AES Deep Space SmallSats: Deep Space Station 17 (DSS-17)



MarCO Demonstrations:

- Downlink Using X-Band Feed and DSN Equipment
- Downlink Using X-Band Feed and MarCO Receiver System
- OMSPA Using X-Band Feed and Custom SDR-based Multiple Receiver System

First OMSPA Demonstration with a CubeSat



First 5 Demodulated Frames from MarCO OMSPA Demonstration on May 6, 2018 from DSS-17,
D. Abraham, Z. Towfic, S. Finley (JPL)
C. Conner, M. Stratton, R. Kroll (Morehead State)

Expands DSN capabilities by utilizing non-NASA assets to provide communication and navigation services to small spacecraft missions to the Moon and inner solar system.

Enabling interplanetary research with small spacecraft platforms

Develops an operational capability to support EM-1 SmallSat missions

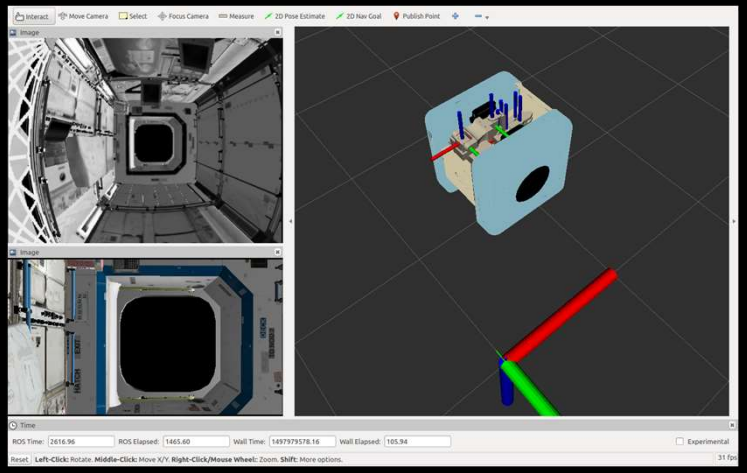
LRO Demonstrations:

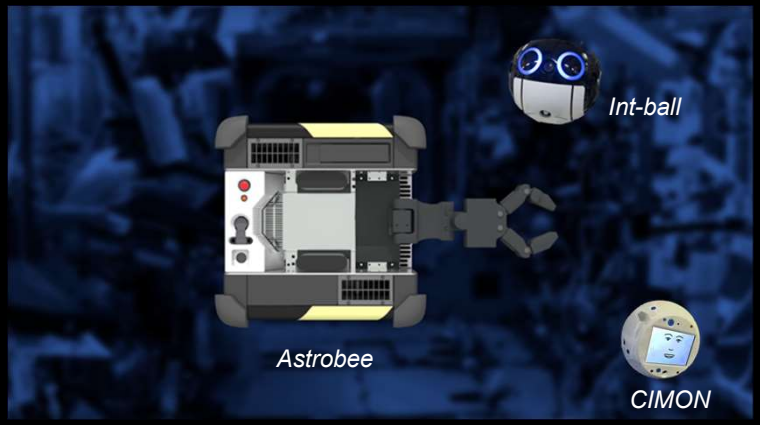
- Routinely Tracking LRO at S-band
- Intermediate Frequency (IF) Systems and DSN Downlink Equipment (DCD, DTT) Verified
- LRO Telemetry Blocks Sent Directly from DSS-17 to JPL DSOC over the NASA Mission Backbone- verifying DSS-17 Signal Path

MSU – Mission Ops Center

A

Astrobee… Next Generation Free Flyer Robot



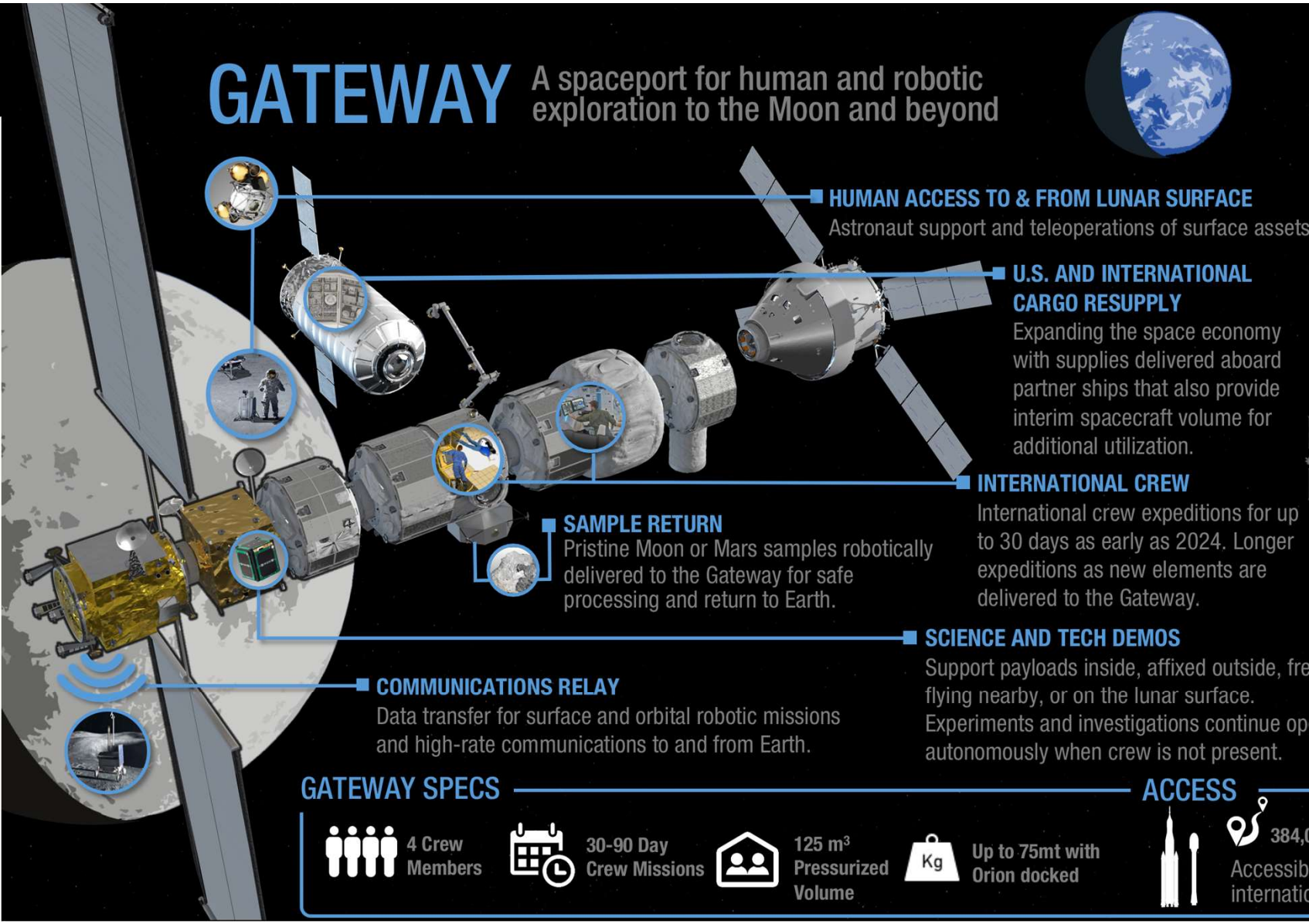


2006 - 2019

Early 2019

GATEWAY

A spaceport for human and robotic exploration to the Moon and beyond



HUMAN ACCESS TO & FROM LUNAR SURFACE
Astronaut support and teleoperations of surface assets.

U.S. AND INTERNATIONAL CARGO RESUPPLY
Expanding the space economy with supplies delivered aboard partner ships that also provide interim spacecraft volume for additional utilization.

INTERNATIONAL CREW
International crew expeditions for up to 30 days as early as 2024. Longer expeditions as new elements are delivered to the Gateway.

SAMPLE RETURN
Pristine Moon or Mars samples robotically delivered to the Gateway for safe processing and return to Earth.

SCIENCE AND TECH DEMOS
Support payloads inside, affixed outside, free-flying nearby, or on the lunar surface. Experiments and investigations continue operating autonomously when crew is not present.

COMMUNICATIONS RELAY
Data transfer for surface and orbital robotic missions and high-rate communications to and from Earth.

SIX DAYS TO ORBIT THE MOON
The orbit keeps the crew in constant communication with Earth and out of the Moon's shadow.

A HUB FOR FARTHER DESTINATIONS
From this orbit, Vehicles can embark to multiple destinations: The Moon, Mars and beyond.

GATEWAY SPECS

- 4 Crew Members
- 30-90 Day Crew Missions
- 125 m^3 Pressurized Volume
- Up to 75mt with Orion docked

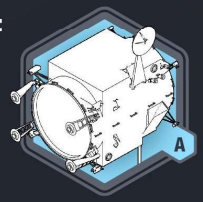
ACCESS

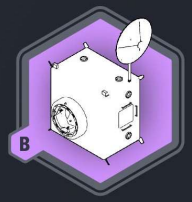
384,000 km from Earth
Accessible via NASA's SLS as well as international and commercial ships.

GATEWAY

An exploration and science outpost in orbit around the Moon

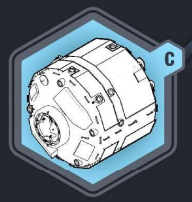
Power and Propulsion Element:
Power, communications, attitude control, and orbit control and transfer capabilities for the Gateway.

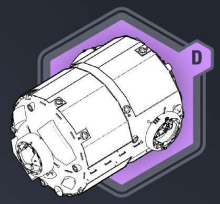


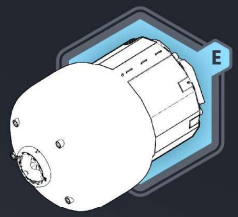


ESPRIT:
Science airlock, additional propellant storage with refueling, and advanced lunar telecommunications capabilities.

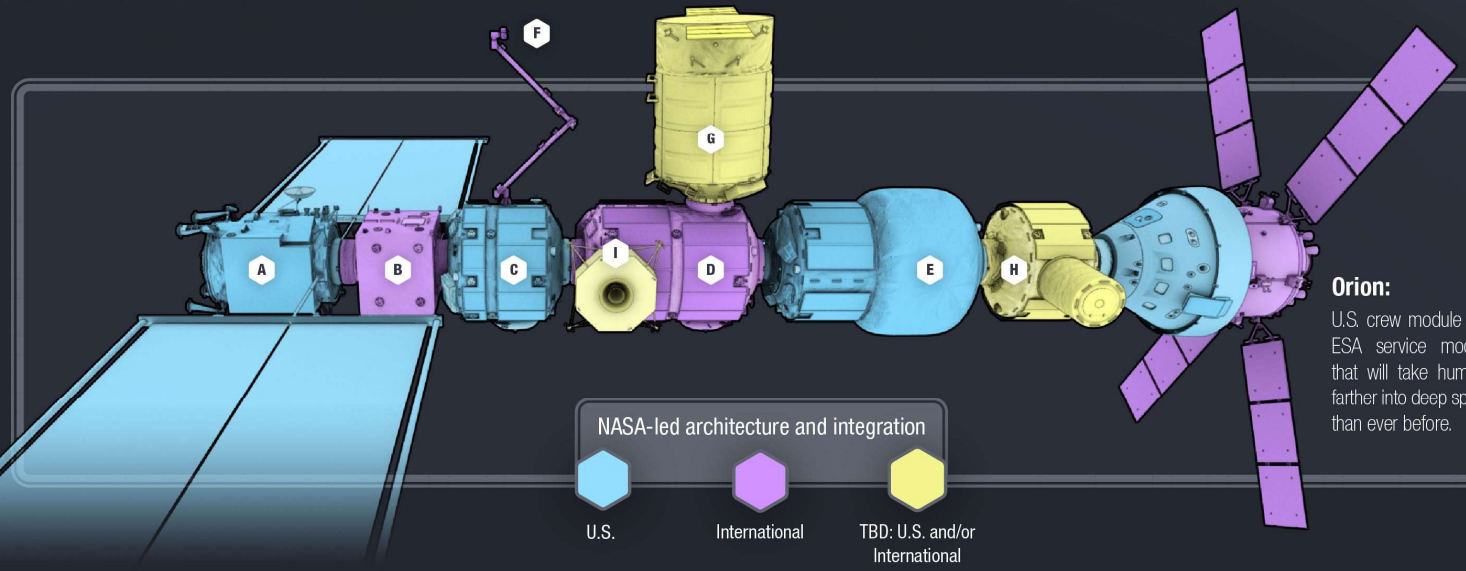
U.S. Utilization Module:
Small pressurized volume for additional habitation capability.





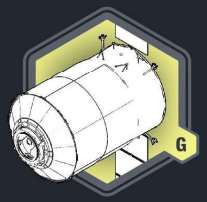


Habitation Modules: Pressurized volumes with environmental control and life support, fire detection and suppression, water storage and distribution.



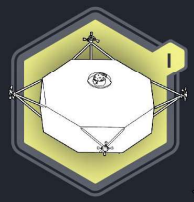
Orion:
U.S. crew module wth ESA service module that will take humans farther into deep space than ever before.

Robotic Arm:
Mechanical arm to berth and inspect vehicles, install science payloads.



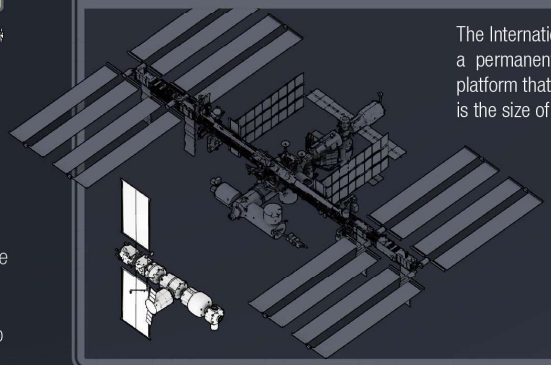
Logistics and Utilization:
Cargo deliveries of consumables and equipment. Modules may double as additional utilization volume.

Airlock:
Enables spacewalks, potential to accommodate docking elements.



Sample Return Vehicle:
A robotic vehicle capable of delivering small samples or payloads from the lunar surface to the Gateway.

Gateway Compared to the International Space Station

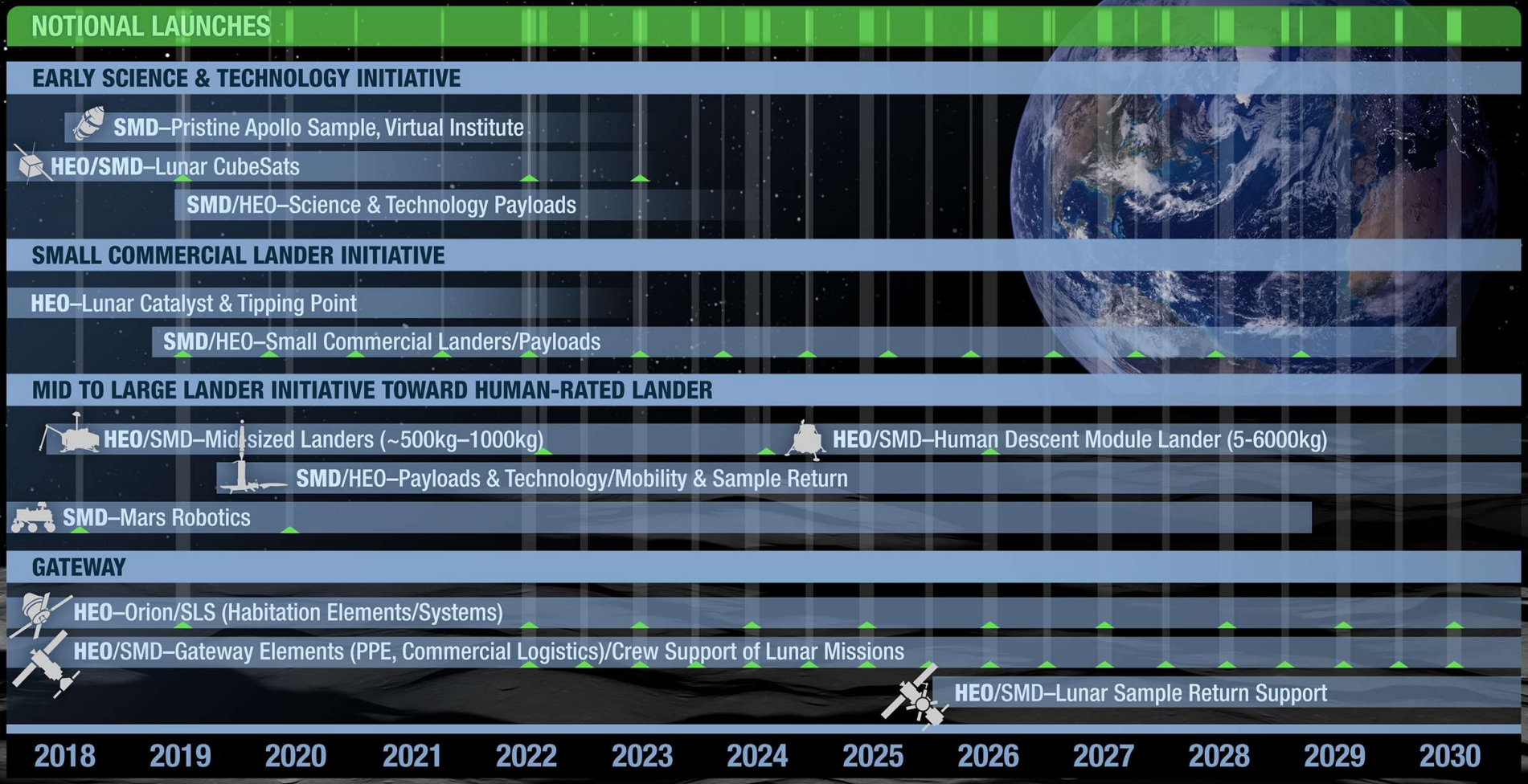


The International Space Station is a permanently crewed research platform that has 11 modules and is the size of a football field.

The Gateway is a much smaller, more focused platform for extending initial human activities into the area around the Moon.

20190727

NASA EXPLORATION CAMPAIGN



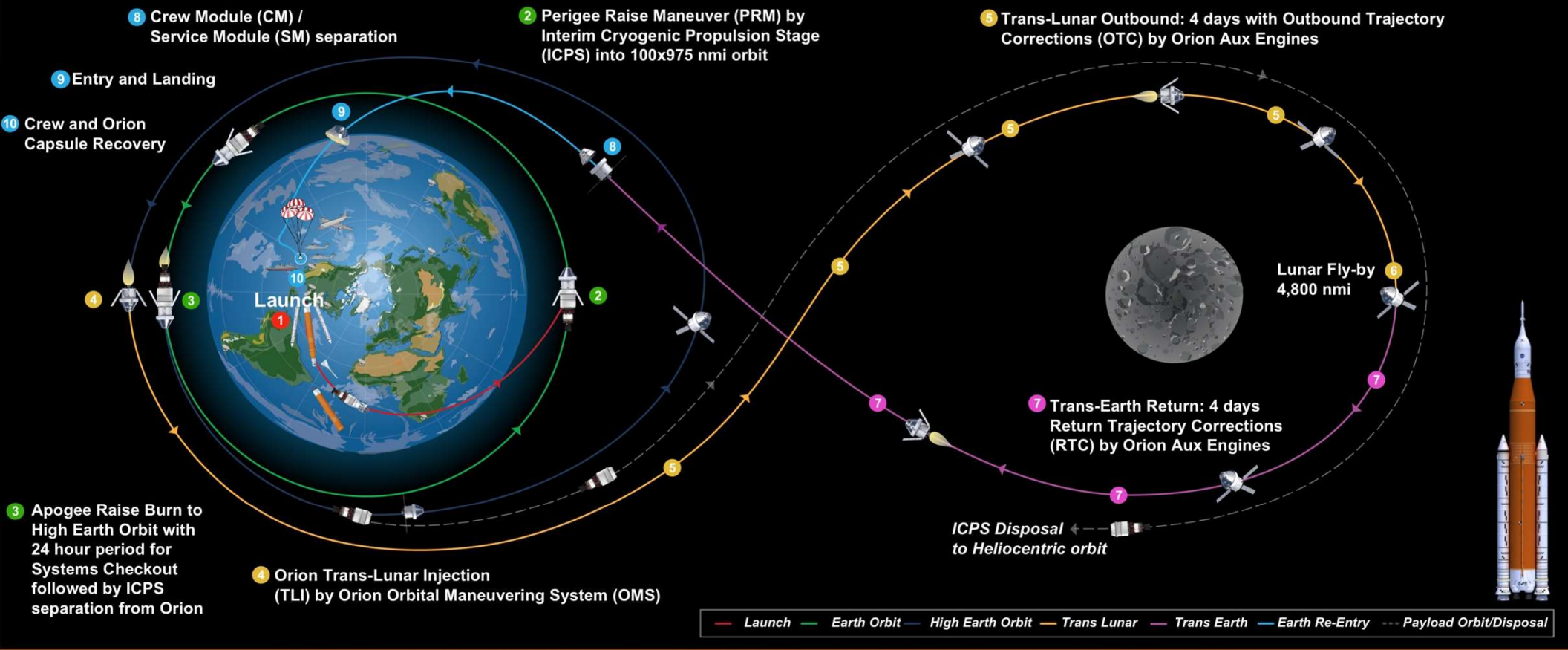
Timelines are tentative and will be developed further in FY 2019

What it Takes to Come Home Safely

LOW EARTH RETURN	LUNAR RETURN	MARS RETURN
3 HOURS	3 DAYS	9 MONTHS
3,000°F	5,200°F	6,200°F
17,500 MPH	24,700 MPH	26,800 MPH
250 MILES	240,000 MILES	39,000,000 MILES

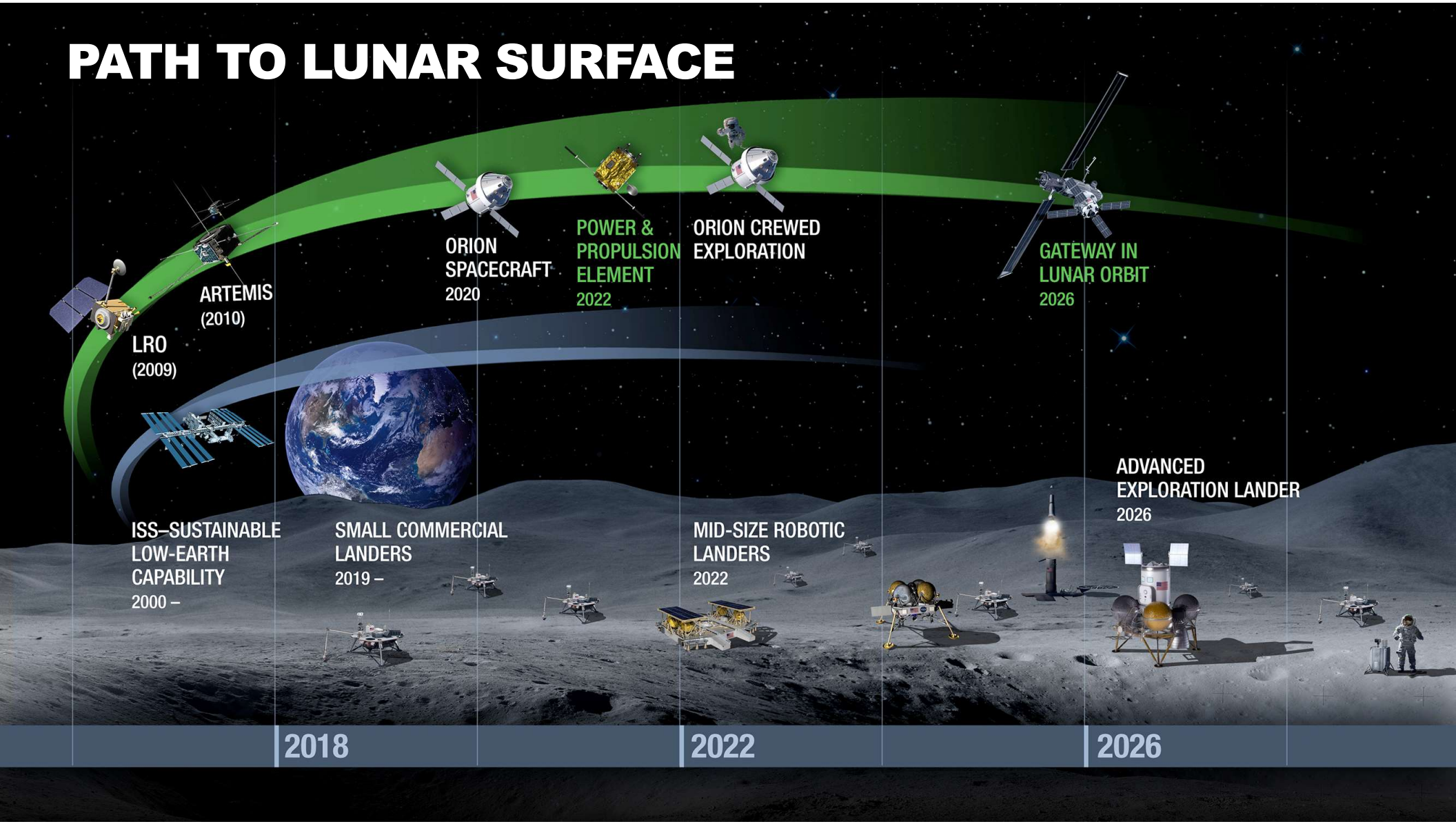
EXPLORATION MISSION-2

Crewed Hybrid Free Return Trajectory, demonstrating crewed flight and spacecraft systems performance beyond Low Earth Orbit (LEO)

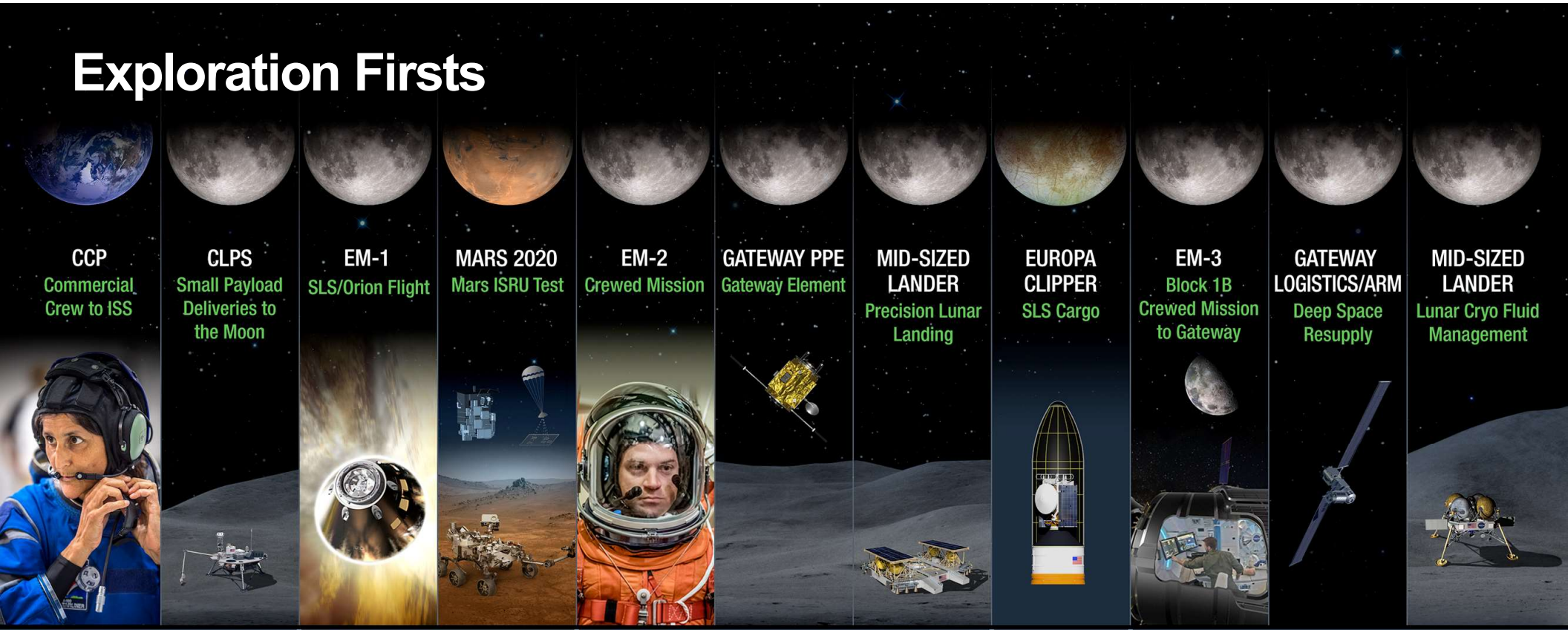


SLS Configuration (Block 1) with Human Rated ICPS | 22x975 nmi (40.7x1806 km) insertion orbit | 28.5 deg inclination

4 astronauts | Total distance traveled: 1,090,320 km – Mission duration: 9 Days – Re-entry speed: 24,500 mph (Mach 32)


PATH TO LUNAR SURFACE
LRO
(2009)
ARTEMIS
(2010)
ORION
SPACECRAFT
2020
POWER &
PROPULSION
ELEMENT
2022
ORION CREWED
EXPLORATION
GATEWAY IN
LUNAR ORBIT
2026
ISS–SUSTAINABLE
LOW-EARTH
CAPABILITY
2000 –
SMALL COMMERCIAL
LANDERS
2019 –
MID-SIZE ROBOTIC
LANDERS
2022
ADVANCED
EXPLORATION LANDER
2026
2018
2022
2026

Exploration Firsts



CCP
Commercial Crew to ISS

CLPS
Small Payload Deliveries to the Moon

EM-1
SLS/Orion Flight

MARS 2020
Mars ISRU Test

EM-2
Crewed Mission

GATEWAY PPE
Gateway Element

MID-SIZED LANDER
Precision Lunar Landing

EUROPA CLIPPER
SLS Cargo

EM-3
Block 1B Crewed Mission to Gateway

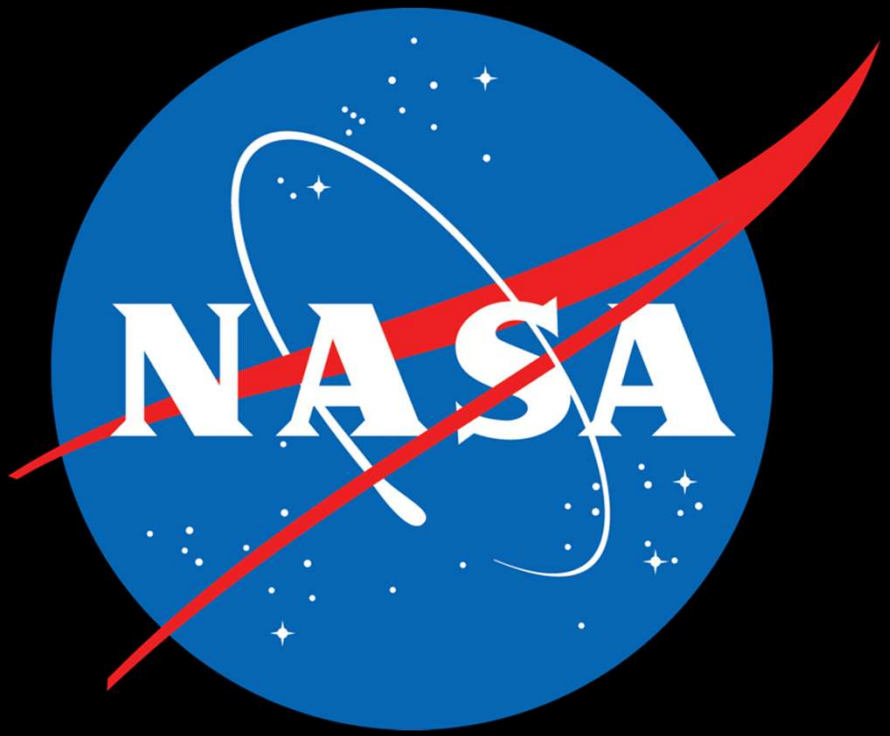
GATEWAY LOGISTICS/ARM
Deep Space Resupply

MID-SIZED LANDER
Lunar Cryo Fluid Management

2019	2020	2022	2023	2024

< **2018** Mars InSight Lander

Lunar/Mars Sample Return **2026** >



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